CRAB ISLAND REVISITED : REASSESSMENT OF THE WORLD'S LARGEST FLATBACK TURTLE ROOKERY AFTER TWELVE YEARS

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Crab Island in northeastern Gulf of Carpentaria supports the largest nesting population of *Natator depressus*, a marine turtle endemic to the Australian continental shelf, and low density nesting by *Eretmochelys imbricata*. The reproductive status of the Flatback Turtle, *Natator depressus*, at Crab Island, is reassessed after 12 years based on a survey conducted during high density nesting in July 1991. *N. depressus* hatchling productivity from the island continues to be high. The characteristic small size of nesting females and egg diameters of *N. depressus* that breed in the Crab Island region suggests that this population is a different breeding unit from that of the southern Great Barrier Reef. The feeding areas supplying turtles to the Crab Island region rookeries extend as far north as southern Irian Jaya. □ *Natator depressus, Eretmochelys imbricata, Crab Island, Queensland, Australia, nesting, hatchling productivity, conservation status.*

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Crab Island, in the north eastern Gulf of Carpentaria, supports the largest recorded nesting aggregation of Flatback Turtles, *Natator depressus* (Limpus & Parmenter, 1986). *N. depressus* is almost totally confined to the Australian continental shelf and its breeding is restricted to Australia (Limpus et al. 1988). The biology of marine turtle populations breeding on Crab Island was reviewed by Limpus et al. (1983a) based on field surveys of the nesting turtles in 1970-1979. Because the status of this significant turtle breeding population had not been reassessed since that time, a study to redescribe the reproductive biology of the Crab Island turtles after a 12 year interval was undertaken in July 1991, during the high density nesting period identified in previous studies (Limpus et al. 1983a).

METHODS

A two person team camped on Crab Island during 6-22 July 1991 (P.J.C. and K.L.D.C.). The western (ocean) beach of the island was measured along the spring high tide level and subdivided into eleven numbered sectors (each 500m long) from south to north (Fig. 1) using a pedometer. All data recorded along the island were scored by beach sector. The beach width within sectors 1-10 was measured from the spring high tide level to the crest of the seaward dune adjacent at each sector mark. These were the sectors in which all turtle nesting activity occurred. On arrival, the team counted all existing turtle tracks by species, without attempting to age the tracks. A single track included both the emergence and return crawl of a nesting turtle. All tracks were crossed off in the sand above the high tide mark as they were counted so that previously recorded tracks could be recognised. Thereafter, a track census was conducted daily: all turtle tracks and nests from which hatchlings had emerged from the previous night were counted by species along the western beach. Because two persons could not monitor the nesting behaviour of all turtles ashore for a night along 6km of beach, a subset of the beach sectors (4 to 6) was selected for nightly measurement of nesting success of each turtle. Potential predators of the turtles, their eggs or hatchlings were identified and quantified where possible. This included counting of crocodile and bird tracks. Turtles were recorded in the waters adjacent to the nesting beach during the daily census of tracks on those days when the weather was relatively calm. As well, a male turtle was captured by 'beach jumping' (cf. Limpus & Reed, 1985).

Opportunistic tagging of nesting female turtles occurred when volunteer members of the Queensland Turtle Research Project visited Crab Island (28 December 1989 and 15-17 January, 1991) and the south beach at the mouth of the Jardine River on the mainland, 14km from Crab Island (29 December 1987). Adult turtles were tagged using serially numbered, self piercing, self locking tags applied to the axillary flipper tagging position (Limpus & Reed, 1985). In July 1991, 3.3g monel tags (National Band and Tag Company, style 1005, size 681; SD = 0.01g, range = 3.25-3.29, n = 50), inscribed with a return address on the reverse side (Ecology, Box 26 Woden 2606 Australia), were used. On the other visits, 4.1g titanium turtle tags (Stockbrands Co. P/L., return address: Wildlife Box 155 North Quay 4002 Qld Australia; Limpus, 1992) were used. The turtles were double tagged, one tag in each front flipper. No attempt was made to tag all turtles ashore in any one night. The measurements taken followed the standard methodology of the Queensland Turtle Research Project as described by Limpus et al. (1983a): midline curved carapace length (CCL); clutch count; egg diameter, egg weight (10 eggs randomly selected per clutch); nest depth to the bottom of the egg chamber; incubation and emergence success of clutches; sand temperature at 50cm depth. Samples of eggs and recently dead hatchlings were collected and deposited in the Queensland Museum.

Air temperature, rainfall and wind data have been obtained from the Bureau of Meteorology (Brisbane) for their weather station at Thursday Island (10°35'S, 142°13'E, 60m elevation, 45km from Crab Island). This is the closest weather station to Crab Island for which there is a comprehensive data set. Tidal data for Booby Island was used (Anon, 1990). Booby Island, 47km to the north west is the closest standard port tidal bench mark across open water to Crab Island.

RESULTS

STUDY SITE

Crab Island (10°59'S, 142°06'E. Fig. 1) is a crescentic sand island that measured 6.2km in length along the high tide level of the outer western beach on 6 July. The inner eastern margin of the island was partly mangrove lined with wide inter-tidal mud flats. The western beach was composed of mixed siliceous sand and calcium carbonate (broken mollusc) fragments and was exposed to surf. Beach rock was exposed intertidally in sectors 4 and 5. The vegetation of the foredune nesting habitat of the western beach was variable: *Melaleuca* woodland with a grass and herb understorey in sectors 5 and 6; open woodland of scattered *Casuarina equisetifolia* (sectors 4 and 7); grassland dominated by *Spinifex hirsutus*, *Ipomoea pes-caprae* and *Tribulus cistoides* (sectors 2-4, 5, 8-10); unvegetated sand dune (sector 6). There were no mangroves growing on the western beach. However, there were standing dead mangrove trunks on the northern part of the western beach that were the result of past encroachment of the island into the mangrove forest. The dead mangroves and beach rock were not an impediment to the nesting activities of the turtles.

Crab Island lies within a region with a distinct summer wet season and winter dry season. The mean monthly rainfall and the mean daily minimum and maximum temperatures for the years 1950-1991 at Thursday Island ranged from 4mm in September to 419mm in January (Fig. 2). Crab Island has no surface freshwater for most of the year. There is an ephemeral freshwater swamp system behind the dune in the northern end of sector 5 which supports at least one species of frog, *Limnodynastes ornatus* (QMJ31755-7). This swamp was dry during the July visit and in most years there would be insufficient rain to refill the swamp until January, which is the peak of the wet season (Fig. 2). Monthly mean daily maximum temperatures ranged from 31.2°C in November to 27.7°C in July, while monthly mean daily minimum temperatures ranged from 25.4°C in December to 22.5°C in July. During the middle of wet season months of January and February the wind is predominantly from the west and northwest and is mostly weaker than 20km/hr. In the middle of dry season months of May to October there are almost no westerly or northwesterly winds; the dry season winds come predominantly

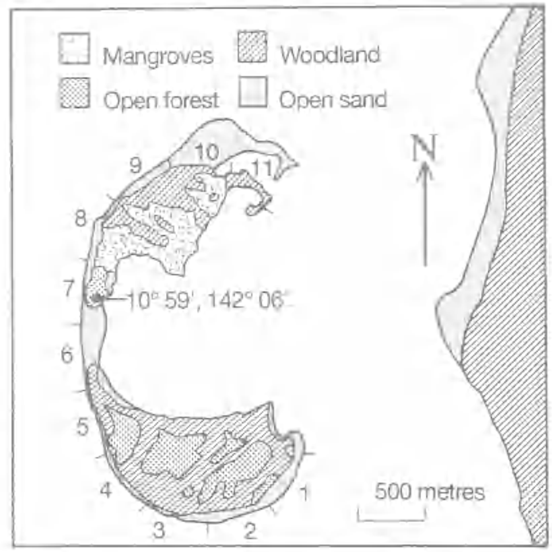

FIG. 1. Map of Crab Island showing position of numbered beach sectors and vegetation types.

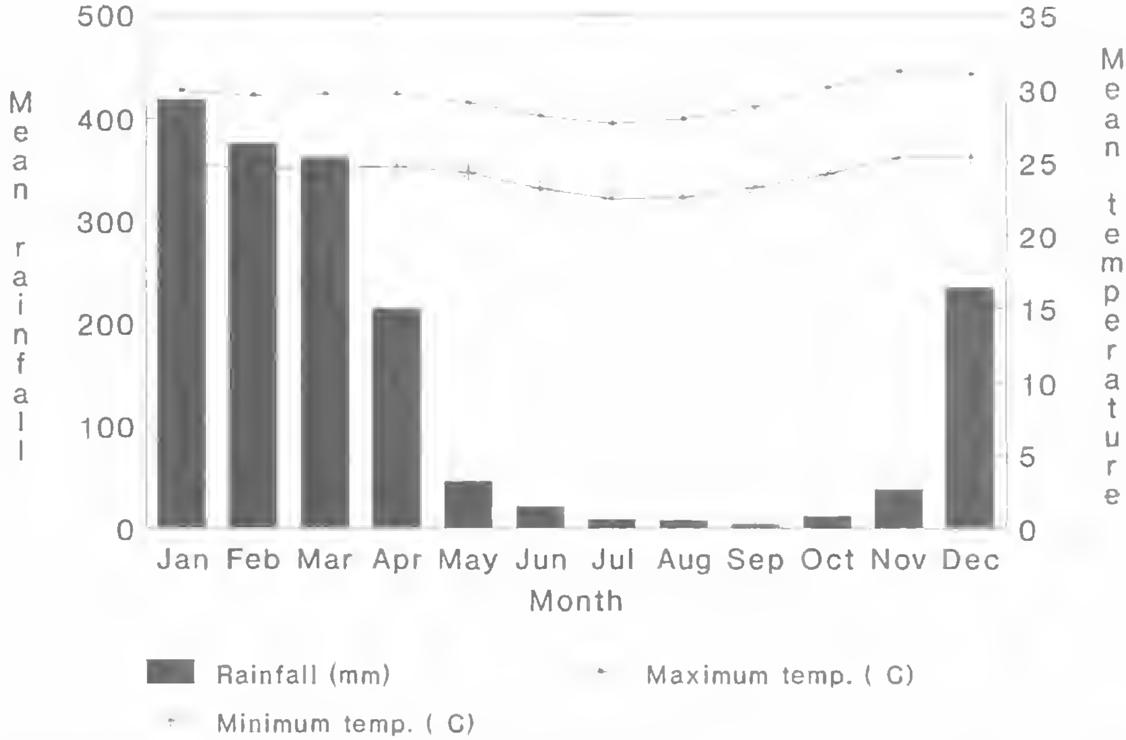

FIG. 2. Monthly mean rainfall (mm) and monthly mean daily minimum and maximum temperatures recorded at Thursday Island Meteorological Station for the years 1950-1991.

from the east and southeast and are mostly stronger than 20km/hr. Mean sand temperature at 50cm depth within the turtle nesting habitat was 27.6°C (SD = 0.49, range = 26.4 - 28.5, n = 44, 1 - 5 measurements per night).

The mean beach width above the spring high tide level was 31.3m (SD = 15.3, n = 10). The narrowest beach (8m) occurred at sector mark 3 and the widest (53m) at sector mark 10. There are two high tides per 24hr at Crab Island (Fig. 3). During 6-22 July, 1991, the daily tidal range varied from 3.46m (12th) to 2.36m (19th). The variation in night time high tide height (0.27m) was less than that of the daytime high tides and both sets of low tides (Fig. 3).

NESTING TURTLES

On the team's arrival at the island on 6 July, 1991, there were 309 turtle tracks visible (174 *N. depressus*, 135 not identifiable to species). Based on nightly track counts from the 14 nights 6-19 July (Fig. 3), there was an average of 132.7 beachings of *N. depressus* per night (SD = 52.11, n = 14, range = 68-235) from a total of 1839 recorded beachings. Similarly, there was an average of 0.6 beachings of *E. imbricata* per night (SD = 0.93, n = 14, range = 0-3) for a total of 9 beachings.

On the limited data from this visit, there is a suggestion that the maximum nightly nesting density may follow the occurrence of afternoon high tides. Only *N. depressus* was recorded coming ashore for nesting during daylight hours (19 [1.0%] of the 1839 total beachings). Most (4 and 13) of these daylight nesting emergences occurred on two days only (8th and 9th July, respectively) with the remainder being single beachings on each of the 10th and 20th July. All except one of the daylight beachings occurred on days with mid-afternoon high tides (8th-10th) while the remainder coincided with a midday high tide (20th).

Turtle nesting activity was restricted to the western (ocean) beach, except for one turtle which came ashore on the western side at the narrow middle of the island (sector 6) and returned to the sea on the eastern side. Most nesting activity occurred within the middle sectors 4-8 (Fig. 4) where the beach width ranged 26-43m. The number of turtle beachings varied nightly and among sectors. The densest activity occurred in sector 5 (nightly mean number of tracks = 43.9,

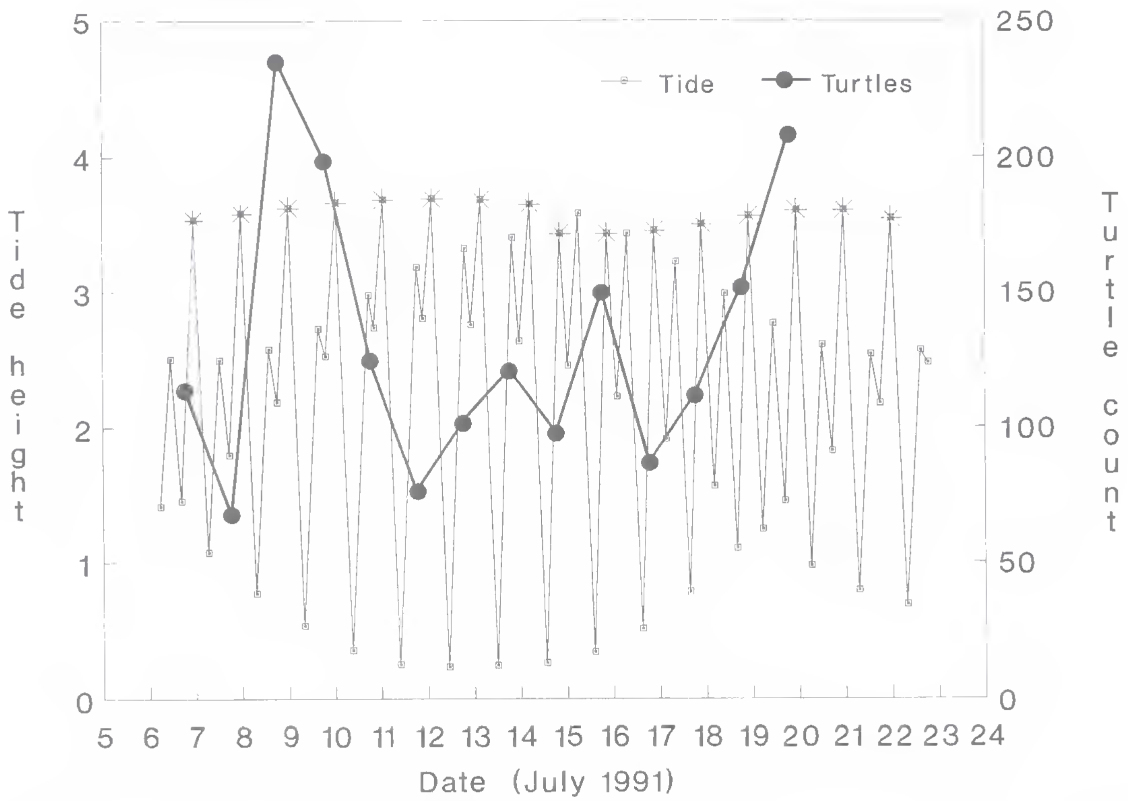

FIG. 3. Daily frequency of beachings by nesting Flatback Turtles, *Natator depressus*, at Crab Island during 6-19 July 1991. The daily variation in tide height (in metres), measured at Booby Island is also shown. *denotes a night time high tide.

SD = 25.49, n = 14, range = 21 - 102) while no tracks were recorded on any night in sector 11.

For the sample of 172 beachings by *N. depressus* examined for nesting success, 132 females (76.7%) definitely laid eggs, 14 (8.1%) could not be determined for nesting success and 26 (15.2%) returned to the sea without laying eggs. Thus there was a probability (±95% confidence limits) of between 76.7±3.2% and 84.8±2.8% that a turtle would successfully lay eggs when she came ashore. When this nesting success probability is applied to the track counts for the period 6-19 July, it is estimated that between 1352 and 1611 *N. depressus* clutches were laid on the island during the 14 nights of observation.

For the sample of 6 beachings by *E. imbricata* examined for nesting success during the same period, 4 laid and 2 did not lay. This represents a nesting success of 67% for this species with an estimated total of 7 clutches laid during the 9 beachings.

Over the 15 nights, 6-20 July, 489 nesting turtles were examined and tagged (483 *N. depressus* and 6 *E. imbricata*). There were no recaptures of any turtles that had been tagged during previous visits to the island, nor were there migrant recaptures of any turtles tagged at other locations. The size distribution of these nesting turtles are summarised in Table 1 and Fig. 5. The mean CCL of the nesting turtles was: *N. depressus* = 88.2 cm, *E. imbricata* = 83.9 cm.

TURTLES ADJACENT TO BEACH

By day when the weather was calm during 6-21 July 1991, there were numerous sightings of solitary turtles surfacing to breathe, mostly within 50m of the beach. All were adult sized *N. depressus*. Up to 15 such turtles were observed adjacent to a single sector during a track census with 0-49 isolated turtles seen during a single track census along the entire beach. The water was clear enough at high tide for adult sized *N. depressus* resting on the bottom at 2m depth to be visible from a dingy adjacent to the beach. In addition, mating turtles were observed in the surf adjacent to the beach on four days (0-2 courting pairs per

TABLE 1. Curved carapace length (cm) of nesting female turtles on Crab Island and adjacent beaches since the studies of Limpus et al. (1983a).

Species	Location	Date	Mean	SD	range	n
Natator depressus	Crab Island	15-16 Jan 1991	90.3	2.49	85.0-95.5	18
		06-20 Jul 1991	88.2	2.80	77.0-95.6	315
	mouth of Jardine River	29 Dec 1987	88.8	0.47	88.5-89.5	3
Eretmochelys imbricata	Crab Island	28 Dec 1989	86.0	—	—	1
		06-20 Jul 1991	83.9	2.41	79.5-86.5	6

daily track census). All were mounted pairs of *N. depressus* and no attendant males were observed. One mounted male (B0314) was captured and measured : CCL = 83.1cm, tail length beyond the carapace = 22.0cm (Fig. 6). The adult male *N. depressus* was similar to the adult female (Fig. 7) in most external features: colour, low doming of the carapace along the midline and lateral upwards reflexing of the carapace (Limpus et al., 1988). The only observed external dimorphic characters were tail length (male very long vs female short) and claws (male elongate and strongly recurved vs female short and slightly curved). The male was mounted on the female, venter to dorsum (Fig. 8), and was gripping the female's carapace margin via the single recurved claw on each flipper. The male was mounted well forward on the female such that his head could rest on her anterior carapace and dorsal neck. His snout contacted her head when she raised her head for a breath.

ADULT MORTALITY, INJURIES AND DISEASES

No dead turtles were found along the beach on arrival on 6 July. The highest and narrowest dunes on the island were in sector 4. The 10m high dune front in this area was steep enough for most turtles to have difficulty in climbing it. One female *N.*

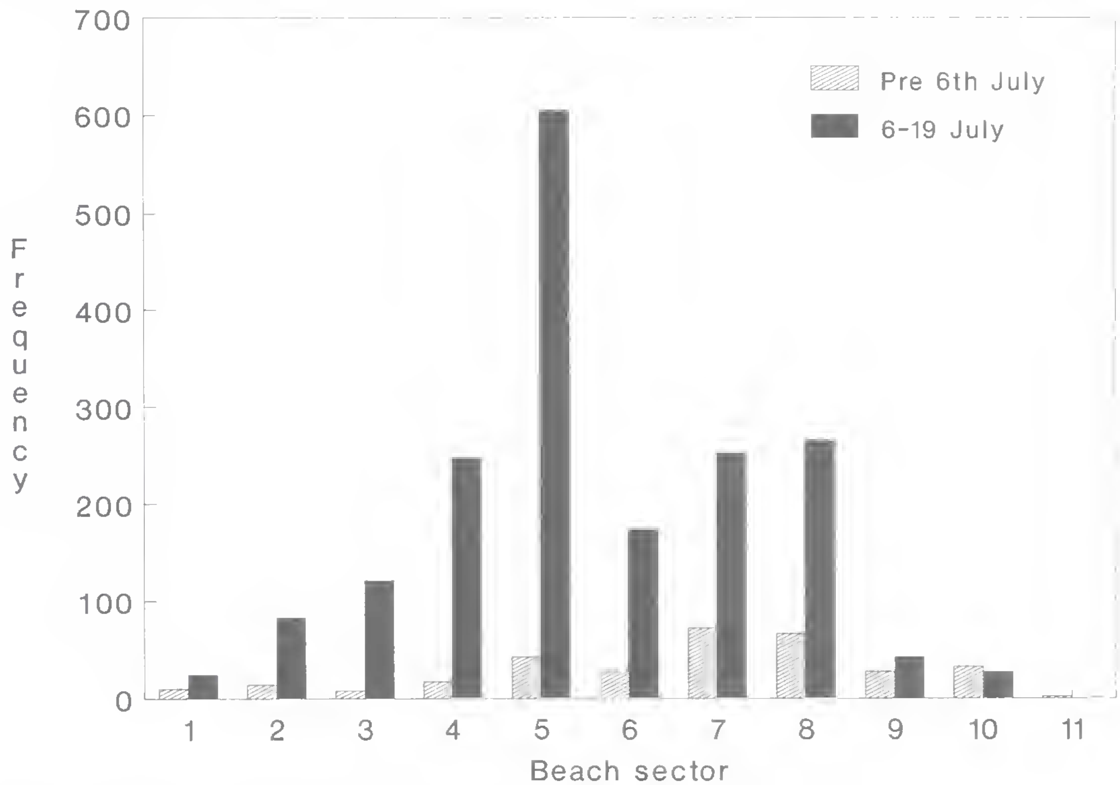

FIG. 4. Distribution of turtle tracks by beach sector on Crab Island, 6-19 July 1991.

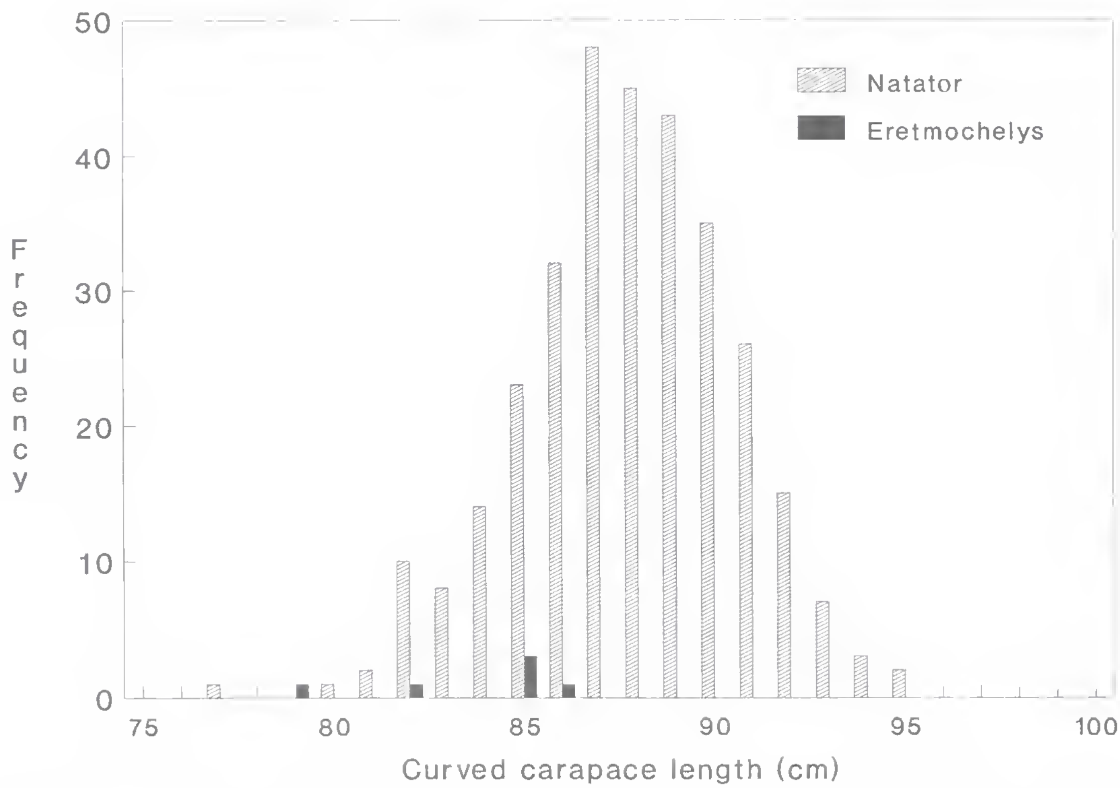

FIG. 5. Size distribution of nesting female *Natator depressus* and *Eretmochelys imbricata* at Crab Island, 6-20 July 1991.

depressus was observed to climb this dune and attempt to nest inland of the dune crest. Later, after wandering to the inland base of these dunes, she was able to find her way back to the beach and return to the sea. A search of the woodland and forest areas inland of the dune crest throughout the island revealed the old fragmented skeletal remains of two adult sized *N. depressus* lying ventral side down behind sector 4. These remains were consistent with the turtles having died after being disoriented following a nesting attempt inland of the crest of the high dunes. No nesting females died while ashore during the 6-21 July 1992 visit.

One large crocodile, *Crocodylus porosus*, (total length 3+m) was observed on most days during late mornings at the water's edge in sector 3. While this crocodile was large enough to be a predator of adult turtles, no turtles showed signs of having been mauled by a crocodile. Several nesting turtles did, however, have healed crescentic damage to the carapace that was presumed to have resulted from past shark or fish bites. For *N. depressus*, loss of large crescentic pieces from the carapace was recorded for 8 (1.7%) turtles, minor carapace damage was recorded for 17 (3.5%) turtles and loss of one third or greater of a flipper was recorded for 32 (6.6%) turtles. All of these injuries were from well before the current nesting season as indicated by their completely healed state. None of the *E. imbricata* showed signs of significant injuries.

Fibropapillomas were recorded on five of the nesting *N. depressus* only: B505, 2 fibropapillomas on neck; B535, 2 on right hind flipper; B625, 1 on right front flipper; B690, 1 on the right shoulder; B1165, 1 on neck. The largest fibropapilloma was 2.4cm in diameter. The ventral surface was not examined.

CLUTCHES

For *N. depressus*, the mean clutch count was 55.9 eggs (Table 2, Fig. 9) and the mean egg diameter was 4.93cm (Table 2). Of the 32 clutches counted at oviposition, one contained one yolkless egg and none contained multiyolked eggs. During the laying of these 32 clutches the

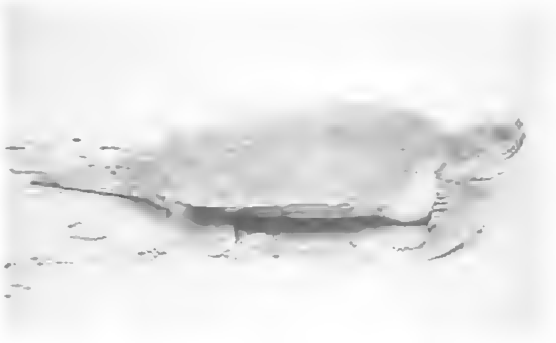

FIG. 6. Adult male Natator depressus, tag number B0314, returning to the sea after being brought ashore for tagging and measurement.

nesting females did not dig into any existing clutches.

For *E. imbricata*, the mean clutch count was 139.3, the mean egg diameter was 3.60cm and the mean egg weight was 26.1g (Table 2). None of the four clutches counted at oviposition contained yolkless or multiyolked eggs. During none of the five successful nestings observed did the turtle dig into an existing clutch.

Representative eggs were collected : 6 normal *N. depressus* eggs, QMJ31745; 1 yolkless *N. depressus* egg, QMJ31747; 3 normal *E. imbricata* eggs, QMJ31746.

Emerged Clutches

Eighty four freshly emerged clutches were identified to species by examination of eggs, hatchlings or hatchling tracks. All were *N. depressus* clutches. Representative hatchling *N. depressus* were collected : QMJ31748-31753. Strong winds prevented the accurate count of emerged clutches for all beach sectors on most nights. Within the relatively wind protected area of sector 5, the nightly number of emerged clutches was counted on 6-15 July. The mean number of *N. depressus* clutches emerging per night in this sector was 4.1 (SD = 2.23, range = 0-8, n = 14 nights, 57 nests). The maximum number of emerged clutches counted along the entire beach on a night with light wind was seven, with four of those in sector five. Hatchlings were often encountered crossing the beach at night but none were seen by day.

Forty nests from recently emerged clutches were dug to assess hatchling incubation and emergence success. After having been laid, two of these clutches had been each dug into by another turtle, representing a clutch disturbance rate after having been laid of 0.05. Another of these 40 emerged clutches had been laid by a turtle that had dug into an existing clutch (clutch disturbance rate at laying = 0.025). Because these latter eggs were adjacent to another previously emerged clutch they could not be counted accurately. Counts were made from the remaining 39 freshly emerged clutches (Table 3). There was no significant difference (t test, p,<<0.05) between mean clutch count measured at laying (Table 2) and mean clutch count measured at emergence (Table 3, Fig. 9), the latter having been laid approximately two months earlier. The mean depth to the bottom of these nests was 58.3 cm (Table 3). There were yolkless eggs (1 per clutch) in two of these clutches.

From the 2129 eggs in the 39 clutches counted, there was a mean hatching success of 81.84%, while hatchling emergence from the nest to the beach surface represented 78.56% of the eggs laid (Table 3). Egg mortality was distributed as follows: 10.4% unhatched, 7.4% undeveloped and 0.3% predation by ghost crabs, *Ocypode* sp (3 nests). Within the nests, there were dead hatchlings representing 2.4% of the eggs laid. A further 0.9% of the eggs were represented by live hatchlings that may or may not have escaped from the nests, had they not been excavated. This included 9 hatchlings that were tangled in a buried branch over one nest.

Egg and Hatchling Predation

There was no evidence of known egg predators such as varanid lizards or large mammals (pigs, dogs, cats) on the island.

Nankeen night herons (*Nycticorax caledonicus*) including adults and fledged juveniles were present in the nesting habitat each night and were observed eating hatchling *N. depressus*. These birds were most concentrated in beach sectors 4-5. At night, up to 6 birds were observed around a nest taking hatchlings as they emerged. This

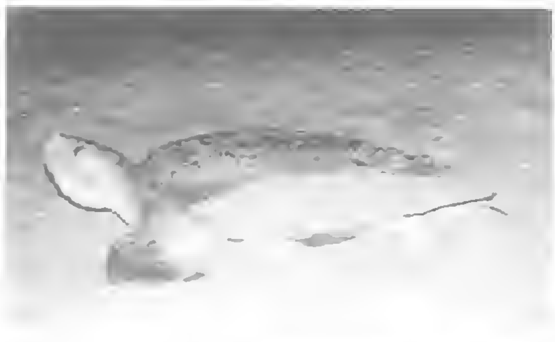

FIG. 7. Adult female *Natator depressus* returning to the sea after nesting on Crab Island.

TABLE 2. Clutch counts and egg measurements recorded from nesting turtles at Crab Island, 6-20 July 1991.* denotes ten eggs measured per clutch.

Species		Mean	SD	range	n
Natator depressus	clutch count	55.9	9.57	34-74	32
	egg diameter(cm)	4.93	0.173	4.52-5.17	60*
Eretmochelys imbricata	clutch count	139.3	10.30	123-151	4
	egg diameter(cm)	3.60	0.071	3.49-3.77	30*
	egg weight (g)	26.08	1.075	24.0-28.0	30*

species was observed also scavenging on turtle eggs that had been dug up by a nesting turtle. Silver gulls (*Larus novaehollandiae*, 1 pair present) flew away with two *N. depressus* hatchlings that had been released from an emerged clutch excavated during the afternoon.

Other potential predators of turtle hatchlings within the nesting habitat and beach area were: water python (*Morelia mackloti*, population estimate not attempted; 1 specimen collected, QMJ31754), estuarine crocodile (*Crocodylus porosus*, minimum of five individuals, including three whose hind foot print lengths were 27, 22.5 and 17.5cm), beach thickknee (*Burhinus neglectus*, several groups of 2-3 birds), osprey (*Pandion haliaetus*, 1 pair), whistling kite (*Haliastur sphenurus*, 1 bird), white breasted sea eagle (*Haliaeetus leucogaster*, 1 pair), frigatebird (*Fregata* sp., 1 bird). Potential predators of turtle hathlings in the adjacent surf included: Australian pelican (*Pelecanus conspicillatus*, flock of 10), numerous small black-tipped whaler sharks (*Carcharhinus* sp.).

On the team's arrival at the island, there were two recently used fire places with broken *N. depressus* egg shells and fish remains in sectors 5 and 7. During the 17 days the team was at the island, three parties of local residents from adjacent mainland communities visited to collect turtle eggs. Turtle nests were located by probing the sand in old body pits with a spear. All three parties directed their egg collecting activity in sectors 5-8, the area of highest density turtle nesting: 14 July three men collected an estimated equivalent of four clutches of *N. depressus* eggs; 17 July a party of adults and children collected multiple clutches of turtle eggs: 21 July three men collected an undetermined number of turtle eggs. On the 22 July, a fourth party from two dinghies visited the island, but the purpose of their visit was not assessed. One of the nests dug on 14 July contained eggs with dried egg shell, i.e. it was not freshly laid. The collector expressed the view that these particular eggs were of marginal quality for eating and only half of the clutch was taken and the remainder reburied.

OTHER INCIDENTAL DATA

During a visit on the night of 29 December 1987 to the south of the Jardine River mouth, three *N. depressus* were tagged in the first 100m and several others could be seen further along the beach (E. Evans, in litt.). G. Kyriazis (pers. comm.) walked the beach along the mainland coast from 1 to 3km south of the mouth of the Jardine River during early September 1991. His impression of the track density at this time was that it was comparable to the track density on Crab Island in July 1991. There was one freshly dead *N. depressus* that had died on its return crawl to the sea after nesting. Pigs were recorded to have destroyed most of the hundreds of turtle nests seen on a 6km section of this mainland beach in the early 1980s (B. Gray, pers. comm.) and local residents continue to identify pig, dingo and varanid predation of eggs as common on this beach (G. Kyriazis, pers. comm.). The size range of female turtles tagged while nesting on other occasions during 1987-1991 at Crab Island (n = 19) and the Jardine River mouth (n = 3) are summarised in Table 1. The majority of turtles encountered on these occasions were *N. depressus*.

RECAPTURES

One long distance migration has been recorded from these taggings. An adult female *N. depressus* (T40505), which had been tagged while nesting at Crab Island on 15 January 1990, was captured in a fishing net off Merauke (8°30'S, 140°22'E) in southern Irian Jaya on 10 January

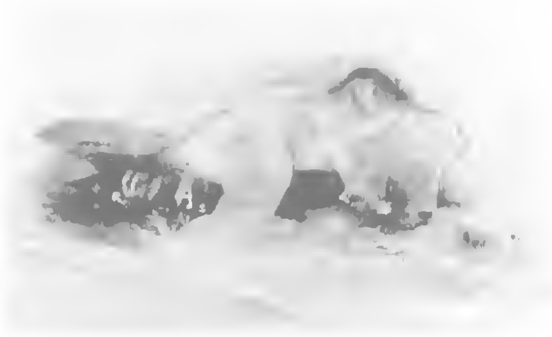

FIG. 8. Adult male *Natator depressus*, tag number B0314, mounted on female prior to capture in approximately 0.7m deep water adjacent to the beach. The female has just surfaced for a breath.

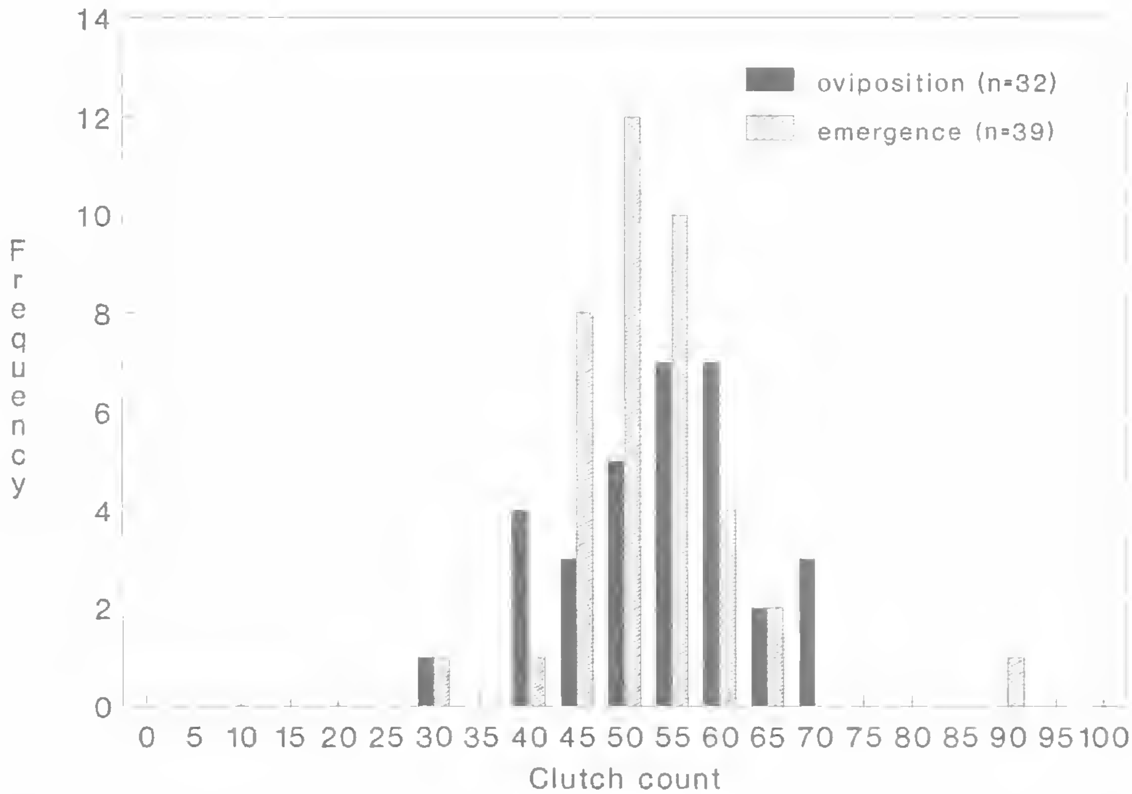

FIG. 9. Frequency distribution of *Natator depressus* clutch counts measured at oviposition and at clutch emergence, Crab Island 6-20 July 1991.

1992. This turtle was eaten. The recapture was made 310km from the nesting beach and two years after she was tagged. This is the first record of *N. depressus* from the coastal waters of Irian Jaya.

One remigration recapture has been recorded from these taggings. *N. depressus* (B1181) was recorded nesting back at Crab Island on 11 September 1992, approximately fourteen months after her initial tagging at Crab Island on 20 July 1991.

DISCUSSION

Marine turtle nesting at Crab Island was first quantified in November-December 1970 (Bustard, 1972). There were subsequent brief visits to further quantify nesting density and to tag nesting turtles during 1976-1979 (Limpus et al., 1983a). As a result of these surveys, Crab Island was found to support all year round breeding and was identified as supporting the largest recorded *N. depressus* nesting population. Low density *E. imbricata* and sporadic *Lepidochelys olivacea* nesting was also recorded for the island. Specimens of *N. depressus* were collected from Crab Island in January 1981, but the nesting population was not described (Zangerl et al., 1988). The island has remained unsurveyed for marine turtles since August 1979. Limpus et al. (1989) identified that *N. depressus* nesting occurs widely in western Torres Strait, with another large nesting concentration at Deliverance and Kerr Islands. The results of the present study allow for a re-evaluation of the status of this significant turtle rookery after 12 years.

Marine turtles typically lay multiple clutches within a single nesting season at approximately two weekly intervals, except for *Lepidochelys* spp. (Hirth, 1980; Limpus et al., 1984). Not all individuals in a particular population begin or complete nesting at the same time of the year (Limpus, 1985). At rookeries in eastern Australia where *Caretta caretta* and *Chelonia mydas* have a discrete nesting season, 60-70% of the total nesting population for the year can be expected to be recorded during a two week tagging census at

TABLE 3. Incubation and emergence success recorded from 39 freshly emerged *Natator depressus* clutches excavated for counting on Crab Island, 6-22 July 1991.

		Mean	SD	n	range
emerged hatchlings		42.9	12.99	39	17-87
hatchlings in nest:	live	0.5	1.73	39	0-10
	dead	1.3	2.51	39	0-11
eggs	unhatched	5.7	5.98	39	0-22
	undeveloped	4.1	5.10	39	0-30
	predated	0.2	0.59	39	0-3
clutch count		54.6	9.37	39	34-94
nest depth (cm)		58.3	7.21	36	43-71
Hatching success %		81.84	17.29	39	26.5-100.0
Emergence success %		78.56	18.55	39	25.0-100.0

the peak of the nesting season (Limpus, 1985 and unpublished data). Therefore a two week census of the Crab Island nesting population at the peak of the nesting season also is presumed to sample a similar proportion of the total population. However, there is all year round nesting at Crab Island (Limpus et al., 1983a) and the present study may not have sampled at exactly the peak of the nesting season. Each of these factors would reduce the proportion of the total population sampled during the two week census. Therefore, the estimated 1352-1611 clutches laid during the 14 nights, 6-19 July 1991, indicate that in excess of 2200 female *N. depressus* were breeding at Crab Island during the 1991 breeding season. While there are insufficient data to identify any changes in the size of this nesting population since it was last surveyed during 1976-1979 (Limpus et al., 1983a), Crab Island continues to support the largest recorded breeding aggregation for this marine turtle. However, it should be remembered that many *N. depressus* nest on the adjacent mainland and that the species also nests on the islands extending to the north throughout western Torres Strait (Limpus et al., 1989). The total annual breeding population for *N. depressus* in the Crab Island region (northeastern Gulf of Carpentaria and western Torres Strait) remains imprecise, but must number many thousands of females. There is still no evidence that Crab Island is of anything but minor importance for nesting by other marine turtle species.

As of March 1993, there has been only one reported feeding ground recapture, a female *N. depressus* from the south eastern Irian Jaya coast, out of the many turtles tagged while nesting in the Crab Island region (1040 *N. depressus*, 11 *E. imbricata*, 1 *L. olivacea*: Bustard, 1972; Limpus et al., 1983a; present study). There have been more than 50 recaptures of *N. depressus* reported from the east coast prawn fishery from inside the Great Barrier Reef (GBR) and central Torres Strait, which had been tagged while nesting at the central Queensland rookeries (Limpus et al., 1983b; C. J. Parmenter, pers. comm.). This suggests that the *N. depressus* population nesting at Crab Island does not migrate from the feeding areas along the eastern Queensland coast. No tagged *N. depressus* from Crab Island has been reported from the northern prawn fishery of the Gulf of Carpentaria and southern Arafura Sea even though several thousand *N. depressus* are captured annually as part of the by-catch of the northern prawn fishery (Poiner & Harris, 1993). This lack of *N. depressus* tag recoveries within the northern prawn fishery contrasts with the occurrence of tag recoveries of *C. caretta* from eastern Australian rookeries in the same fishery (Limpus et al., 1992; Limpus & Reimer, 1993). This suggests that the Gulf of Carpentaria is not a significant feeding area for the *N. depressus* that nest at Crab Island. The one long distance tag recovery demonstrates that the feeding distribution of the Crab Island nesting population extends northwards at least to the southern Irian Jaya coast.

Turtle nesting and hatchling emergence have been recorded at Crab Island on all previous visits (April, May, July, August, November and December) with a seasonal variability in density (Limpus et al., 1983a). The limited data from 1991 also show seasonal variability in nesting density. The high density nesting in July (average 133 beachings per night on the whole beach and

44 beachings per night in sector 5; 77-85% nesting success) contrasts with the low number of clutches emerging at the same time (average 4 emerging clutches per night in sector 5). Because the incubation time for marine turtle eggs is approximately two months, in the absence of evidence of extensive clutch destruction or harvest at Crab Island, these data suggest that the July 1991 nesting density was approximately 10 times the magnitude of the nesting density two months earlier in May 1991. The 6-19 July 1991 nesting density appears to be considerably greater than the density recorded in 15-19 July 1978 but included nights with similar nesting density to that recorded on 13-14 August 1979 (Limpus et al., 1983a). This apparent increase in nesting population as indicated by the July nesting densities could have three different explanations: 1, this between-year vari

ability could be the result of natural annual fluctuations in the nesting population as has been recorded for *C. mydas* in eastern Queensland (Limpus & Nicholls, 1988); 2, the timing of the peak of the nesting season may vary between months in different years; 3, there may have been an increase in the size of the nesting population. Because of the high fidelity that *N. depressus* displays to particular small nesting beaches (Limpus et al., 1984) the possibility that the apparent increase in the Crab Island nesting population could have resulted from inter-rookery movements is dismissed. More extensive surveys of the rookery are needed before the stability of this population can be reliably assessed. Given the extended breeding season and the wide nesting distribution in western Torres Strait, Crab Island and northwestern Cape York Peninsula, the size and distribution of the breeding population cannot be adequately surveyed by brief visits to single localities as has been the pattern to date.

The data collected on this survey of *N. depressus* from Crab Island (Tables 1,2) provide additional support for the conclusion that the *N. depressus* nesting population from the Crab Island region consists of smaller nesting females laying comparable sized clutches of smaller eggs than those of the nesting population at the southern GBR rookeries (Limpus et al., 1989). The hatchling productivity from undisturbed clutches at Crab Island remains comparable to that recorded in previous studies (Limpus et al., 1983a).

The mid-year high density *N. depressus* nesting and associated incubation of eggs at Crab Island spans the months of lowest rainfall and daily air temperature (Fig. 2). This dry season nesting also coincides with the predominantly south easterly winds. Therefore the majority of the turtle nesting occurs on beaches with a westerly aspect; these are usually leeward to the prevailing winds and are therefore less likely to be eroded by wind driven surf when most eggs are incubating. Also, by nesting in the dry season, the turtles might be avoiding egg loss through flooding that could result from a raised water table below the dunes during the wet season.

The sand temperature (mean±SD) at 50cm depth in the nesting habitat for 6-21 July 1991 of 27.6±0.49°C was the lowest recorded in any month at Crab Island (12 Dec. 1976 = 29.6±1.32°C, 8-10 Dec. 1978 = 31.4±0.88°C, 27 April-7 May 1978 = 29.4±1.21°C, Limpus et al., 1983a) or at Deliverance Island (2-4 October 1987 = 29.4±0.95°C, Limpus et al., 1989). However, the year round sand temperatures at nest depth in the Crab Island area remain above 24°C, the approximate lower limit for successful incubation of marine turtle eggs from all species (Miller, 1985). This facilitates the observed all year round successful nesting by marine turtles in the Crab Island region, although the mid-summer sand temperatures approach 34°C which is the approximate upper lethal incubation temperature for marine turtle eggs (Miller, 1985). In contrast, at the rookeries in central and southern Queensland, the winter sand temperatures at nest depth fall below 24°C and consequently, successful marine turtle nesting can only occur there during the warmer summer months (Limpus, 1971; Limpus et al. 1981). In northern Australia there has probably been a selective advantage for marine turtles to aggregate their nesting into the mid-year when sand temperatures are well separated from the lethal limits of incubation temperature (Guinea 1993).

The pivotal temperature, the theoretical temperature at which a 1:1 sex ratio could be expected, is not fixed for *Caretta caretta* or *Chelonia mydas* but varies between breeding units. While within each breeding unit, the species reproduces regionally on beaches that provide a range of nest temperatures spanning the pivotal temperature (Limpus et al., 1983c; C. Limpus, unpublished data). The pivotal temperature for *N. depressus* from the southern GBR region is 29.5°C, ranging from 100% male hatchling production at 28°C to 100% females at 31°C (C. Limpus, unpublished data). Based on the recorded sand temperatures at Crab Island (see above), if the Crab Island region population had the same pivotal temperature as the southern GBR population, Crab Island would be producing mostly male hatchlings during the mid-year high density nesting, while mostly females would be produced from the low density summer nesting. However, if the Crab Island region nesting population is part of a separate breeding unit from the southern GBR population, then different pivotal temperatures could occur for the populations. This would then allow for the possibility of the Crab Island nesting population fitting the model that a turtle breeding unit chooses its nesting beaches such that its pivotal temperature occurs within the range of sand temperatures at nest depth that is available during the main nesting season. This would require that the Crab Island region and southern GBR nesting populations represent different *N. depressus* breeding units. The differences in adult and egg size between the northeastern Gulf of Carpentaria and southern GBR *N. depressus* populations also support the hypothesis that these populations are separate stocks. A precise estimate of the *N. depressus* hatchling sex ratio from Crab Island cannot be made from the available data.

The local peoples of northern Cape York Peninsula, western Torres Strait and Irian Jaya harvest small numbers of adult *N. depressus* and numerous clutches of eggs annually from this population (Johannes & MacFarlane, 1991; Limpus et al., 1983a, 1989; present study). The impact of each of these village-based harvests should not be considered in isolation. Indeed, the harvest at any one nesting beach or by any one village should be assessed within the regional context of the total breeding population. In relation to this, the significance of egg losses through harvest and predation to the regional population poses major uncertainties. If the mainland beaches have a different sand composition and hence sand colour, they would have a different temperature profile from the islands. In particular, darker sands would be warmer and result in a higher proportion of females from these mainland beaches (c.f. the situation for *Caretta caretta* in southeastern Queensland, Limpus et al., 1983c). The indicated high predation levels by pigs, dingoes and varanid lizards on the eggs laid on the mainland beaches has the potential for threatening the survival of the entire population in the long term. The observed egg harvest by local people of a few clutches each week from Crab Island could be sustainable during the mid-year high density nesting. However, if the rate of harvest is constant throughout the year and the off-peak nesting produces mostly female hatchlings, then the loss of additional female hatchling production through egg harvest must be considered in conjunction with the impact of the egg predation on mainland clutches. In addition, what impact the drowning hundreds of *N. depressus* annually in fishing gear in the northern prawn fishery (Poiner & Harris, 1993) and other Gulf of Carpentaria fisheries (P. Couper, unpublished data) has on the Crab Island nesting population needs clarification. These *N. depressus* mortalities in the dispersed feeding areas represent additional losses to this population that have commenced in recent decades. Before it can judged as to whether the current level of harvest of *N. depressus* eggs and turtles by the local peoples from these rookeries of the northeastern Gulf of Carpentaria and western Torres Strait is sustainable, the breeding unit of these turtles needs to be aligned to geographic boundaries and population size and anthropomorphic mortality for the population throughout its range quantified. In addition hatchling productivity and associated sex ratio should be quantified from the significant rookeries within the region. When these types of data are available, the long term viability of this most significant *N. depressus* population and the associated harvests can be more reliably assessed.

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